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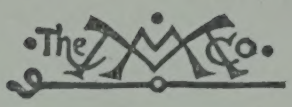
MODERN BREAD FROM THE VIEWPOINT OF NUTRITION



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MODERN BREAD
FROM THE VIEWPOINT OF
NUTRITION

by

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and

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Columbia University

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PREFACE

REALIZATION of the fact that white bread, while highly developed technologically, was nutritionally an impoverished product, has recently led to several plans for its enrichment.

The use of dried skim milk in breadmaking has rapidly grown to a point at which a large proportion of the baker's bread used in the United States has become nutritionally a much improved food. Another new method for the nutritional improvement of bread is the use of vitamin-rich yeast. Another is the retention of wheat germ in the flour or the return of the germ to the dough in breadmaking. Still another, is the introduction of vitamins and mineral salts in pure form or as artificial concentrates.

The discussion of these various plans—all motivated by the desire to compensate, in some sense, for the rejection of nutrients in the roller process of milling white flour—has redirected attention to the possibilities of reducing these losses by so milling the wheat as to retain more of it in the bread flour.

Moreover, legal regulations permit combinations of these different ways of attaining the status of enriched flour or bread. Hence, there are actually many different kinds of enriched bread and of gradations between the kinds officially distinguished.

The whole legal and technological situation is still in a somewhat formative state.

In this discussion of modern bread, therefore, it has seemed best to make the major divisions of our text in terms of the outstanding nutritional factors in which breads may differ and which the nutritionally minded consumer will hold permanently in view, however great the variety of breads offered at any given time and place.

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MODERN BREAD FROM THE VIEWPOINT OF NUTRITION

Chapter I

PROGRESS BRINGS NEW BREAD PROBLEMS

Its traditional characterization as the staff of life places bread in the position of an exceptionally constant staple. This importance is also reflected in Egyptian and Biblical history and in the fact that Plato proposed to have bread the central feature of the food supply of his Republic. Yet the history of wheat and of bread is a history of changes and of problems.

WHEAT

The origin of the bread wheat is itself a problem. When prehistoric man developed a preference for this particular kind of seed, the problem arose of favoring the growth of the grass which bore it, as against the hardier, more sod-forming grasses. In this the farmers of the Nile Valley were helped by the annual inundations which tended to drown out the sod and bury it in deep deposits of silty soil especially suitable for wheat culture.

Egypt's premier wheat and bread supply was one of its distinctions among the ancient nations of the Mediterranean world, spreading to Palestine, Greece, and Italy, where the Romans experimented in the improvement of their wheat crops through seed selection, choice of soil, and mode of cultivation. Wheat culture was also one of the first and longest lines of research undertaken in the pioneer agricultural experiment station established by Lawes and Gilbert at Rothamsted, England, in 1843. Here the effects of rotation of crops and of the artificial fertilization of the soil, as well as its mechanical cultivation (and, later, its microbiology), were especially investigated.

A little later the American agricultural experiment stations were established. The building of railroads and the use of steel-faced plows brought large areas of range land into cultivation. The production of wheat for export to Europe became a great industry, and researches in wheat breeding, cultivation, fertilization, and irrigation were developed actively.

Wiley (1907) considered that probably no other crop was more influenced in its properties by environmental factors than is wheat. Bailey (1925)*

* When name and date are given in the form just used or in such form as "Stiebeling and co-workers (1941, p. 57)," the reader who desires may thereby identify the original publication in the collective bibliography appended to this text.

devotes thirty pages to the influence of environment on the composition of wheat. By the regulation of the environment and by selective breeding, wheats especially designed for the production of breadmaking flours were developed.

FLOUR

Much excellent scientific work has been done in the breeding, selection, and milling of wheat to produce flour of the desired breadmaking qualities. (See, for instance, the periodical, *Cereal Chemistry,* and the excellent book, *The Chemistry of Wheat Flour,* by Bailey in the Monograph Series of the American Chemical Society.)

According to Bailey, it is those zones of the endosperm which lie next to the aleurone layer that contain most of the gluten and so give most "strength" to the flour. See Bailey (1925, pp. 140, 142) for a diagram of five zones of endosperm with gluten contents progressing from 7.4 per cent in the innermost zone to 16.5 per cent in the zone next to the aleurone layer.

Other topics treated by Bailey in such a manner as to show the reader that each has been the subject of much research are: the storage and handling of wheat, its examination for possible defects, the various criteria for judgment of the

fineness (not merely mechanical but rather the degree of artificial refinement) of flours, change of flour incidental to aging, the color of flour and flour bleaching, flour strength as related to enzyme phenomena, and as determined by the proteins of flour and colloidal behavior of dough.

Progress also wrought changes in the methods of milling and breadmaking, some of which introduced much more far-reaching problems than could be foreseen.

From time immemorial, wheat had been ground between millstones, latterly with subsequent sifting-out of the coarser particles before using the flour to make bread. When wheat was milled between stones, all the parts of the grain were more or less ground down together. The starchy endosperm was most completely powdered, passed most completely through the bolting cloth with which the flour was sifted, and so constituted the greater part of the bolted flour which the old-fashioned mill produced for breadmaking. But this stone-ground bread flour also contained particles of the germ (embryo), of the fibrous bran, and of the yellowish horny aleurone layer which lies between the bran coats and the pulverulent endosperm. A simple diagram showing the parts of the wheat kernel has been published by one of us elsewhere (Sherman, 1933, p. 289), and much more detailed

accounts and illustrations are readily available in reference books and wall charts. The stone-ground flour used in making the light bread of our grandparents (and theirs) was not strictly white but rather cream-colored. When closely compared with the dead-white flour from the roller mills, the stone-ground flour appeared not only yellowish from its particles of germ and aleurone but also slightly "specky" from the tiny brownish particles of bran, a few of which were small enough to pass through the bolting cloth.

Between 1880 and 1885, the grinding of wheat between stones was very generally (and in a few more years almost completely) replaced by the process in which the grain is crushed between steel rollers instead of being ground between stones. The outstanding difference is that the inner, starchy, pulverulent endosperm of the grain is rubbed off from the flattened bran and germ with very little disintegration of either of the latter into particles fine enough to pass through the bolting cloth into the flour. Thus the typical roller-process flour is finer and whiter because it consists more exclusively of the most starchy part of the grain. But nutritionally, any process representing in the millers' sense a "cleaner" separation of the white, easily powdered, starchy endosperm from the embryo and outer layers of the grain must necessarily

yield a flour poorer in the mineral elements and vitamin values of the wheat. In fact, flours are commercially graded as finer the lower their mineral content or ash.

Another nutritional difference, probably much more important than is generally recognized, is that the protein mixture of the wheat kernel as a whole is more efficient in nutrition than that of the endosperm alone. Doubtless one reason for the lack of general recognition and adequate appreciation of this fact is the great discussion, in the flour trade and in baking technology, of protein quality as a technological, but not as a nutritional, concept. Whereas in the literature of nutrition protein "quality" means the amino-acid constitution which gives the protein its greater or lesser nutritional efficiency (or supplementary value), in the literature of milling and breadmaking it means the presence of such proteins (and in such quantitative relations to each other) as make a physically strong gluten and dough and a resulting porous, "well-piled" loaf of the desired texture.

BREAD

According to Bailey, leaven was systematically used in breadmaking in Egypt by about 2000 B.C.; and Cathcart (1941) remarks that the control in

the fermentation of bread dough has been an art combined in ancient times with superstition and in modern times with science. The latter points out that the chemist Dumas, writing in 1843, first advocated the determination of the baking value of flour by means of baking tests conducted under strict laboratory control. Thus chemistry has aided baking about a century, but only during the past quarter century have bakers generally come to use tests carried out with the precision of laboratory work in the exact sciences. In fact, baking for a time lagged behind other fermentation industries in scientific method but during the past two or three decades has brought its applications of chemistry and microbiology to high standards.

As Cathcart (1941) points out, scientific progress in the baking industry has two main aspects: (1) development of new materials and methods and (2) accurate control work to ensure a uniform finished product with the qualities desired by the trade. Chemistry has not only applied established analytical methods to the baking industry, as in the precise quantitative analysis of flours to determine the relation of slight fluctuations in percentages of constituents to the properties of the dough and the resulting bread, but it has also devised special methods, based on modern physical and colloid chemistry, to determine the elasticity and

strength of the protein combination of given batches of flour as worked up into bread dough. The "gassing powers" of flours have been correlated and measured through the diastatic (amylolytic) activities; and, similarly, the proteolytic with the gas-retaining property. Thus the diastatic and proteolytic enzyme activities of flours are now regularly measured and systematically controlled: the diastatic by selection of the wheat and the regulated use of malt extracts; the proteolytic by means of maturing agents.

The scientist also furnishes the baker with uniformly standardized yeast. But this is only part of the yeast control. A large baking company having manufacturing branches in different regions found that centralized training of operators and control of flour and yeast as practiced from two to three decades ago still did not ensure strict uniformity of the bread produced in its different bakeries. Research showed the differences to be due to the small amounts of natural salts in the water supplies and resulted in the working out of salt mixtures * which correct the differences in local water supplies, increase and regularize the activity of

* Developed in the Mellon Institute for Industrial Research, the original mixture was named from the initials of the first directing chemist of the Institute, Robert Kennedy Duncan, i.e., "R.K.D. (Arkady) yeast food." Such salt mixtures are now commonly called "dough conditioners" or "yeast conditioners."

the yeast, and help to control and stabilize the enzymic activity and physicochemical condition and behavior of the dough—all, of course, contributing to uniformity of properties in the bread finally resulting. These are only a few illustrations of the scientific controls in modern breadmaking.

Thus, through the contributions of chemistry and the cognate sciences applied to the study of the soil, the fertilizer, the water supply, the wheat itself, and the milling process, it became possible for the miller to produce a flour of uniform properties, transportable to any part of the world, and from which the baker could make a well-piled loaf of bread uniformly of the texture, flavor, and color desired.

This was a triumph of technological science, but meanwhile nutritional science has also been making important advances.

How does the "fine" white product of the modern milling and baking technology as developed up to 1940 appear in the light of the newer chemistry of nutrition? The chemical factors of which the highly developed scientific controls of milling and baking had taken account up to about 1940 fall far short of the list of factors we now know to be nutritionally essential.

The function of food is to nourish. How well does the white bread, which the trade has hitherto

rated as best, show up when studied as a source of the now known essentials of adequate and well-balanced nutrition? And is there any functional (physiological) reason why consumers should prefer to eat the product of the white flour which the trade prefers to handle? To help toward a sound answer to this question is one of the main reasons for the chapters which follow. Meanwhile, it may be said at this point that what degree of fineness one should logically prefer in one's bread depends in part upon the amount of bread that one consumes each day. Hence the present chapter ends with a backward glance from this point of view; after which the more strictly nutritional aspects of the bread problem will be taken up in sequence in the chapters that follow.

According to Baker, Wright, and Drummond (1937), the masses of the English people (and probably of Northern Europeans generally) subsisted two centuries ago very largely upon coarse, dark, heavy breads made chiefly from rye and barley.

Wheat bread, lighter both in color and texture, was the food "of the gentry" and was coveted by the common people not only in social imitation but because the more porous texture of "light" wheat bread is a real gain to the comfort and hygiene of the digestive process when large quan-

tities of bread are consumed. Also, when one eats a pound or more of bread a day and must make up the remainder of a high food-need very largely by the cheaper vegetables, there is doubtless good reason for a desire to reduce the amount of daily roughage, to relieve the digestive tract from the excessive irritation caused by large amounts of the harsh outer bran coats of the grain. Even the rice-eating masses of the Orient, who for centuries have been compelled to greater economy than are we, have similarly rejected the outermost layer of their food grain.

Now (1941), as a result of the reconsideration of the bread problem, it is being shown possible to free the wheat kernel of that outermost coat which does involve digestive difficulty for some people, and at the same time to retain in the bread flour a higher proportion of the weight and of the nutrients of the wheat. To this we shall recur in subsequent chapters.

Chapter II

FUNDAMENTAL CHARACTERISTICS OF BREAD AS FOOD

The bread of a century ago, that of a decade ago, and all of the staple breads of today are of about equal value as food fuel, as sources of energy in nutrition. This is a very important aspect of nutrition, and factor in food value.

In so far as hunger and appetite guide us to eat about as much food as we nutritionally need, this instinctive meeting of need is more nearly true of the need for food energy (food "calories") than of the need for protein or probably for any of the mineral elements or vitamins.

If we say that bread is still the staff of life, we mean in terms of the nutritional concepts of today that, in the dietaries of most people or in the food supplies of most nations, "bread" (in the sense of all breadstuffs and related cereals) goes farther to satisfy hunger and is a larger source of the energy needed in nutrition than is any other kind of food.

Through all the technological developments in the production and milling of wheat and the baking of bread, the energy value of the product has remained practically unchanged at about twelve hundred Calories per pound or seventy-five Calories an ounce.* Of the various plans now being considered for the enrichment of bread, all have to do primarily with other nutritional factors and will leave the familiar and long-established energy value of the bread substantially unchanged. An energy value of approximately seventy-five Calories an ounce may therefore be regarded as a fundamental and permanent property of bread as a food.

To some extent this fact is considered when deciding the proper amount of any mineral or vitamin enrichment to introduce in order that the Enriched † bread shall "carry its share" of the mineral element or vitamin value in question. To some extent, also, the consideration of enrichment of bread is guided by a "philosophy of restoration" of wheat bread to something approaching

* The science of food and nutrition regularly makes use of the "greater calorie" (the Calorie) as its most convenient unit of energy. Following the terminology of the exact sciences, we here use the capital initial *in those cases in which quantitative statements are being made* but not in cases of merely general mention of the energy aspect of food values.

† "Enriched" is the term authorized by the United States Food and Drug Administration.

the nutritive character of wheat iself. We shall encounter some of the influences of these viewpoints in later chapters.

A high proportion of our food calories has been and is furnished by bread and equivalent grain products. This continues to be an outstanding feature of the food supplies of the great majority of the world's peoples and of the majority of families in our own and most other nations, notwithstanding some decreases in per capita consumption of breadstuffs during the past few decades.

The following estimates are believed to be typical, and sufficiently accurate to afford a sound general grasp of this fundamental fact.

At the time of this writing, the latest publication of Stiebeling and co-workers (1941, p. 57) shows breadstuffs and equivalent grain products furnishing 25 per cent of the total food calories in the dietaries of typical (white) farm families of the North and West, and 38 per cent in those of comparable economic condition in the Southeast, of the United States. In families of lower income, a still higher percentage of the total food calories is taken in the form of breadstuffs.

Typical estimates from summaries in other Government publications and by Cummings (1940) show 19 per cent of the food calories furnished by

breadstuffs * in the dietaries of professional men's families, 27 per cent in well-to-do farm families, 39 per cent in workingmen's families, 54 per cent in poor Southern farm families.

Stiebeling and Ward (1933) in their dietary plans for different levels of nutritive content and cost showed, in the diet recommended for emergency use, 43 per cent of the food calories from breadstuffs; in "adequate diet at minimum cost," 35 per cent; and in "adequate diet at moderate cost," 24 per cent. Here the terms "minimum cost" and "moderate cost" were used in a most liberal sense, and the dietary plans suggested were not based on purely nutritional and economic considerations but also took very generous account of the American food habits and preferences of the prosperous pre-depression period. This period and its preferences also, of course, antedated much of our present-day knowledge of nutrition and the current interest in nutritional improvement of bread.

In the average dietaries of 26 city families reported by Stiebeling and Phipard (1939) as presumably representative of the East North Central Region of the United States, breadstuffs furnished

* For convenience the term breadstuffs may be used to designate bread, flour, and other analogous cereal or grain products.

31.3 per cent of the total calories at a cost of 18.1 per cent of the money spent for food.

In the average of 224 presumably typical American families representative of all parts of the United States and of several years, breadstuffs (grain products) furnished 38.20 per cent of the calories at a cost of 18.39 per cent of the expenditure for food (Sherman, 1941, p. 510).

Compared with all the rest of a typical American dietary, the breadstuffs may be expected to occupy about twice as large a place in the total calories of the food as in its cost. This is approximately true, whatever the type of bread chosen; but, as will be discussed in the chapters which follow, the value of bread as a source of the other nutritional factors depends upon the kind of bread.

The economy of bread as a fuel food or source of energy and satiety value in nutrition is not the only reason for its prominence in our dietaries. Most people like it and find that it contributes to the comfort of the digestive process.

Good texture in bread, to which cereal chemistry and baking technology are so largely devoted, is important in its appeal to the eye and the palate; and also has further significance for the utility of bread as a food. A texture which ensures thorough chewing thereby contributes to a favorable initiation of the digestive process with benefit to

the comfort and satisfaction of the consumer and the good utilization of the food as a whole.

Also, it is probably of more importance than is generally recognized that the taking of bread with, and especially at fairly frequent intervals throughout each meal, tends to give a desirable texture to the food-mass, a texture which is favorable to the mechanics of digestion throughout the entire alimentary tract. Doubtless it is favorable to the chemistry of the digestive process as well, facilitating the penetration of the food-mass by the digestive juices and the predominance of the action of the digestive enzymes over the less desirable chemical changes induced by certain types of bacteria which all too often gain access to the digestive tract.

Aside from such services to the chemistry, the hygiene, and the mechanics of the digestive process, the porous texture of bread makes it a convenient vehicle for bringing into consumption such other things as butter, peanut butter, meat juices (gravies), and vegetable juices (cooking waters, "pot liquors"). It is a mistake to ignore (whether through lack of knowledge or because of social prejudice) the important service which bread may thus render indirectly to the nutritive value of the dietary as a whole by absorbing the fluid portions of a wide variety of foods and thus preventing

their loss either in the kitchen or at the table.

With the newer knowledge of nutrition has come a greatly increased appreciation of the food values of the juices and cooking waters of vegetables, and it is now commonly taught that these should be carefully saved and worked into soups. The saving and consumption of "pot liquors" by low-income families, perhaps especially in our Southern States, is recognized as a food habit of greater nutritional and health value than we formerly understood. But the commendation of this mode of conserving nutritive values often loses much of its effectiveness either because of the deterioration of the vitamin values of the vegetable juices, drippings, or cooking waters while awaiting (and during) their transformation into soup, or because the amount in evidence at a given time seems too small to be worth the bother of saving and using. Much more effective (usually, at least) is the practice of absorbing the vegetable juice or cooking water directly in bread and eating it at once, in the same way as is often done with the juice of a roast which is being carved at the family table.

For the foregoing and other reasons, the vast majority of the world's people find their largest source of energy in foods made from grains.

By the earth's population as a whole, rice is con-

sumed more largely than any other grain. For many Oriental peoples, rice occupies as large a place in their food supply as do wheat, rye, barley, maize, and potatoes (taken together) in the dietary of the Western world.

As Hopkins emphasized a quarter of a century ago, the growing of cereals generally yields an energy supply for the worker at less cost and with less relative expenditure of time and ingenuity than any other method of food production. In some large and densely populated Oriental regions, rice is the traditional and most popular food grain, but throughout our Western world "economic and social factors", as Hopkins put it, "tend to make bread by far the most convenient form in which the cereals can reach the individual consumer. The nations of the West have acquired the habit of demanding a well-piled loaf, and for this the special properties of wheat gluten seem necessary. Hence the reliance on wheat in the West." (F. G. Hopkins, through Osborne and Mendel, 1919.)

Barley, oats, and rye can be grown with less warmth and sunshine and on thinner soils than wheat and so help man to survive in harsher highlands and in more forbidding latitudes. But to the peoples of Northern Europe, wheat is *the golden grain,* and the great areas of rich wheat-growing

lands on the prairies and plains of America became their land of promise.

Also, mechanical invention greatly expedited the exploitation of these wheat lands. McCollum and Simmonds (1929) emphasized the influence of the modern steel-faced plow in bringing the grasslands of our Western States so rapidly under cultivation. Laborsaving modern machinery for the harrowing of land and the drilling, harvesting, and threshing of the wheat followed rapidly. The large areas of relatively level land permitted the use of large machines so that it has become possible, according to the estimates of Alsberg and of Cooper and Spillman, for each day of man labor on a modernly equipped wheat farm to produce as much protein and calories of human food as a man will consume in a year.

Yet, during the same period in which the nation's capacity for wheat production and its milling and baking technology were so greatly developed, the per capita consumption of breadstuffs in the United States declined at least 20 per cent.

Such a situation obviously accentuates the problem of the place of wheat in the national food supply, and of bread and flour in the individual and family dietary, from a more comprehensive nutritional viewpoint than that of digestibility and energy value alone.

The next three chapters will be devoted to these other nutritional factors; Chapter VI will then return to the problem of the quantitative place which the breadstuffs may well occupy in the dietary of an individual or a family and in the food supply of the nation; and Chapter VII will consider some of the present trends and problems.

Chapter III

PROTEINS

The importance of bread proteins to the nutritional well-being of the individual, family, or nation depends upon how prominent a place the breadstuffs occupy in the dietary or food supply and upon the quantity and quality of the other proteins in the diet. If bread constitutes only a minor part of the diet, the chemical nature and nutritional efficiency of the bread proteins are problems of little consequence. On the other hand, when, as is more often the case, bread provides a high percentage of the calories of the diet, it will provide a fairly high proportion of its protein also, and the chemical composition (amino-acid make-up) of the bread proteins becomes a matter of importance. As this will doubtless continue to be the case with most of the families of all the chief nations, at least of the temperate zones, let us consider the fundamental reasons.

Proteins are essential constituents of both plant and animal cells. There is no known life without

them. It is as true for the human body as for those of other animal species that life could not exist without the proteins of the active cells nor continue without an incessant "turnover" or "exchange of material" between the proteins or protein-building amino acids of the tissues and of the food or its digestion products.

Hence, if human (or other animal) nutrition is to be satisfactory, then the right kind of protein in sufficient quantity must be supplied by the diet. This is true both for growth and for maintenance; in both cases the "right kind of protein," as the phrase is here used, means such a protein or mixture of proteins as yields, when digested, the amount of each "nutritionally essential" or "indispensable" amino acid that the body needs.

The nitrogen, which is the characteristic element of proteins, actually exists in the large protein molecule in the form of about twenty different kinds of amino acids. (Strictly speaking, it exists as amino-acid radicles chemically combined into the protein molecule.) These amino acids are sometimes called the building stones of the protein structures of foods and of the body tissues.

In 1907, Osborne published the results of his very thorough studies of the physicochemical nature and the amino-acid make-up of the proteins of wheat and suggested that, when proteins differ

so much in the kinds of amino acids they contain and in the relative amounts of each, it must be expected that they will differ in their nutritive values.

The subsequent work of several investigators has fully established this view that individual proteins (and the protein mixtures of different foods) may have different nutritive values depending chiefly upon their amino-acid contents.

About half of these amino acids may be made in the body from the others; but ten of them appear to be nutritionally essential or indispensable in the sense that they must be supplied by the food. Hence, the science of nutrition must now take account not merely of the amounts of protein present in different foods but also of the kinds and amounts of amino acids which the protein mixtures of different foods yield to the body.

Research has revealed a great deal as to the nutritional functions of these essential amino acids; and also as to which food proteins contain them, and in what amounts.

If one of the indispensable amino acids is missing from a given food, then that food by itself cannot meet the nutritional requirement of supplying all the needs of the "exchange of material" or the maintenance or upkeep of the body tissues; and the lack would be shown still more quickly

and conspicuously in the inability of the young body to continue its growth.

More frequent than the cases of entire lack are those in which there is a relative shortage of one of the indispensable amino acids; and this thus becomes the *limiting factor*. In such a case there may be suspended or subnormal growth; and a prompt resumption or increase of growth may occur when the diet is supplemented by the addition of the "limiting" amino acid alone, or of any protein which is a good source of it.

For example, on a diet the protein of which contained very little of the amino-acid lysine, experimental animals could not grow or grew only very slowly; but, when enough lysine was added to the diet, normal growth was resumed. Furthermore, when the addition of lysine was discontinued, growth again ceased (or became very subnormal as before).

In this way, Osborne and Mendel showed lysine and tryptophane to be indispensable amino acids, and that the lower nutritional efficiency of the proteins of white flour—as compared with those of whole wheat or of milk, eggs, or meat—is explainable in terms of the lower lysine and trytophane contents of the white-flour proteins.

The amino acids which the body obtains by digestion of the food proteins are important, not

only as building-blocks for construction of the tissue proteins, but also for making the substances concerned in the regulation of some of the physiological processes upon which life and health depend.

For example, insulin, the regulatory substance which the internal secretion of the pancreas contains and which plays an essential part in the regulation of the carbohydrate metabolism, is known to be a compound of nine of these amino acids. Glutathione, a regulatory catalyst acting in the tissue cells in which it is produced, is simpler in its structure, since it is formed of three of the amino acids. On the other hand, typical digestive enzymes are, like proteins generally, so complex that their precise molecular structures have not yet been fully worked out; but are analogous to insulin in that they are essential catalysts formed in the body from the amino acids which the body obtains from the proteins of its food.

How, then, is it possible in everyday life to secure all the amino acids necessary for the proper functioning of the human body?

Instead of supplementing an incomplete protein by the addition of single amino acids (as was done during the investigations previously mentioned), it is convenient and economical to feed mixtures of foods whose proteins supplement each

other because one is relatively rich in the particular amino acids in which the other is poor or possibly lacking.*

Thus the proteins of white flour are relatively poor in lysine and tryptophane, while the proteins of milk, eggs, and meat are relatively rich in both these amino acids.

In an extended series of researches by Osborne and Mendel (1919), it was found that, while the proteins of white flour—even when fed at liberal percentages of the food mixture—supported little if any growth, good growth was obtained when either milk, egg, or meat protein constituted one-third, and white-flour protein two-thirds, of the total food protein.

Our own exploratory research experiments tend to indicate also that, when dried skim milk is used in breadmaking in the proportion of six pounds to each hundred pounds of white flour, the proteins of the latter are so supplemented that the resulting white bread is adequate in meeting the protein requirements of growth. Such bread, however, is not equally adequate as a source of some of the mineral elements and vitamins.

The growth experiments cited in the preceding

* General textbook discussions, fuller than space permits here, of the indispensable amino acids and the supplementary relationships of proteins in nutrition have recently been published elsewhere (Sherman and Lanford, 1940, pp. 90-107; Sherman, 1941, pp. 42-90).

two paragraphs were made with laboratory rats the nutritional processes of which, especially with respect to protein, have been shown to be very similar to those of human beings.

Experiments conducted directly with human beings have also shown that such amounts of milk as are often used in breadmaking suffice to make the protein mixture of white milk-bread quite efficient in meeting all the protein needs of maintenance in men and women (Sherman, 1920).

It is also well worthy of emphasis that the proteins of those parts of the wheat grain which are rejected in the making of white flour are also effective supplements of the white-flour proteins, since the former are relatively rich in those essential amino acids in which the white-flour proteins are relatively poor.

Osborne and Mendel (1919) showed that proteins of whole wheat provided amply for the protein needs of growth, reproduction, and lactation, whereas little if any growth occurred on those diets in which white flour was used instead of whole wheat.

Jones (1925 and personal communication of June 14, 1941) has independently shown the nutritional superiority of whole-wheat protein over white-flour protein. In his parallel experiments with diets containing 92 per cent of whole-wheat

or white flour, respectively, together with 4 per cent yeast, 3 per cent Osborne-Mendel salt mixture, and 1 per cent cod-liver oil, the rats receiving the whole wheat made strikingly better gains, even though here the proteins of the white flour were apparently supplemented significantly by those of the liberal amounts of yeast contained in the experimental diet.

Copping (1939) has summarized the evidence of considerable numbers of nitrogen-balance experiments designed to afford a direct and explicit comparison of the protein (protein mixture) of the entire wheat kernel with that of its endosperm (corresponding to white flour). Here, also, the experimental findings showed decided nutritional superiority of the whole-wheat proteins over the proteins of the endosperm or white flour.

In part, the nutritional superiority of the whole-wheat proteins is attributable to those of the bran (Murphy and Jones, 1926) and in part to those of the germ or embryo.

Wheat germ may, by a recently developed process, be incorporated in the bread dough by the baker, thus improving the nutritive value of the bread protein at the same time that the thiamin content is markedly increased. Both additions can be made without any appreciable change in the desired physical properties of white bread.

It has been reported that the milling process can be so modified as to retain the germ with the white flour from which the bran has been eliminated.

There is also much interest in such modifications of the milling process as reject the outermost coat of the kernel—the rough part which makes strictly whole-wheat flour too harsh for some people—and yet retain the highly nutritious parts which are lost in the making of patent and other "short extraction" flours. By increasing significantly the percentage of the wheat kernel which goes into bread flour, it is possible to have bread which has a much higher vitamin value and the proteins of which are of greater nutritional efficiency. This is now (summer of 1941) being done on a large scale, while at the same time avoiding that degree of roughage which a few people find excessive when they eat considerable amounts of strictly whole-wheat bread.

The proteins of meat and of milk are accounted among those of highest nutritional efficiency. But in directly comparative and carefully controlled experiments, Rose and MacLeod (1925) found that a mixture of equal parts of bread and milk proteins showed as high a nutritive efficiency in adult human maintenance as either milk or meat protein.

Chapter IV

MINERAL ELEMENTS OF WHEAT AND BREAD

Variations in the percentages of the different mineral elements found in wheats grown in various parts of the world are due to many factors, some of the chief being variety, soil, place, and conditions under which the wheat is grown. The further variation in the ash of flour can be accounted for by the fluctuation in the relative proportion of bran and endosperm. In fact, the commercial rating of flours as to degree of refining varies inversely with their ash content. Combining Copping's judgments and our own, we may cite as estimated averages the data collected in Table 1.

As a simple approximation, it may be said that average white flour contains only about one-fourth as much of a given mineral element as does whole-wheat flour, while the so-called Graham and whole-meal flours are rather nearer the composition of whole-wheat than of white flour in this re-

TABLE 1

PERCENTAGES OF CERTAIN MINERAL ELEMENTS IN PRESUMABLY REPRESENTATIVE SAMPLES OF WHEAT AND ITS MILL PRODUCTS

Material	Total Ash	Calcium	Phosphorus	Potassium	Iron	Copper	Manganese
Entire wheat	2.00	0.057	0.374	0.465	0.0057	0.0008	0.0046
Wheat bran	7.00	0.120	1.215	1.217	0.0127	0.0013	0.0107
Wheat germ	4.80	0.071	1.050	0.296	0.0117	0.0010	0.0084
Graham flour	1.70	0.035	0.300	0.324	0.0040	0.0004	0.0043
Whole-meal flour	1.50	0.031	0.238	0.274	0.0025	(0.0004)*	(0.0040)*
White flour	0.43	0.015	0.101	0.130	0.0013	0.0001	0.0007

* The figures given in parentheses in this table rest upon less direct evidence than the others.

spect. The new "peeled" wheat has practically the same mineral content as entire wheat without its harshness of outer fiber.

The practical nutritional importance of these differences will clearly depend largely upon the kinds and amounts of other foods contained in the dietary. In liberal diets an abundance of other foods may fully supply the nutritional differences between the different kinds of bread; but, in low-cost and moderate-cost diets containing more bread and less of other foods, the nature of the bread may very significantly influence the nutritional adequacy of the dietary as a whole.

It may be well at this point to consider the place actually held by the breadstuffs in dietaries of different economic levels.

McDougall (1939) writes of the preponderance of cereals in the rural dietary of Central, Eastern, and Southeastern Europe, where cereals often provide 80 to 90 per cent of the energy value of the diet, that is, fully twice as high a proportion as in Western and Northern Europe. A recent survey by the Ministry of Agriculture of 936 farm households in different parts of Bulgaria shows that an average of 72 per cent of the energy value of the diet is provided for by bread and flour, while in Poland bread and other cereals constitute at least 60 per cent of the diet of the rural population and in Hungary 75 per cent of the total calories of the diet comes from cereals.

In the general average of 224 typical American dietaries, grain products furnished 38 per cent of the calories; and, in an extended series of dietary studies made at the State University of Maine, the grain products furnished 40 per cent of the fuel value (of the diet).

A study of Table 1, showing the mineral constituents of wheat and some of its milling products, will give an idea of the extent of the losses and of the resulting insecurity of low-cost diets which consist largely of such breadstuffs as are

now (1940–41) commonly consumed. It also shows how readily and importantly the situation may be improved. (We may hope that in some cases the improvement will have begun by the time this is read. The chapters which follow will show added reasons for such improvement.)

Further, medical experience in the rearing of children and the experiences of animal husbandry in the rearing of animals agree with the view that the mineral elements of even whole cereals are not ideally proportioned and are not by themselves to be relied upon for the best development of the body. The mineral elements in milk, fruits, and vegetables, especially the leafy vegetables, are better proportioned to the needs of our nutrition.

The following pages review such aspects of this subject as are most directly involved in the nutritional problems of the place of bread in the diet and the relative merits of the different types of bread.

CALCIUM AND PHOSPHORUS

Even whole wheat is not a calcium-rich food. It contains many times more phosphorus than calcium. A considerable part of this phosphorus is in the phytin form, which is of somewhat questionable availability; yet, after making allowance for

this fact, wheat is relatively poorer in calcium than in phosphorus. This is also true of all of the bread flours. Thus, in all dietaries in which bread or cereals play a prominent part, there is more danger of a shortage of calcium than of phosphorus; and the calcium-to-phosphorus ratio is undesirably low. Hence, it is a nutritional gain, both from the viewpoint of this ratio and from that of simple avoidance of a shortage of food calcium, if flour is fortified with calcium (in any of the forms likely to be used) or if milk powder with its liberal calcium content is used in breadmaking. From whichever viewpoint regarded, calcium is much more likely than phosphorus to be the limiting factor. It is also very noteworthy that nutritionists now generally consider it a safe assumption that a dietary satisfactory in other respects may be trusted to supply sufficient phosphorus without any special planning. Accordingly, in the remainder of this section, the discussion is simply in terms of calcium.

It is true that the calcium content of wheat may vary to an extent which is nutritionally significant. At the Utah Agricultural Experiment Station, the Kota variety, when grown under certain cultural conditions, particularly as to soil and abundance of irrigation water, has been found to have a higher-than-average calcium content. Further-

more, Greaves and co-workers have compared this high-calcium Kota wheat with Turkey wheat of average calcium content in a series of experiments with growing rats on suitable mixed diets of which wheat was a major part. These experiments showed that, as compared with those receiving wheat of usual calcium content, the rats on the diet containing high-calcium wheat: (1) made better growth gains; (2) made better bone development as shown by higher percentages of total ash, of calcium, and of phosphorus in the femurs at the end of the experimental period; and (3) showed somewhat higher levels of calcium and phosphorus concentrations in the blood serum. Thus the nutritional superiority of the high-calcium Kota wheat over the Turkey wheat of ordinary calcium content was clearly demonstrated. Probably, however, many years of complicated research will be needed to establish the possibilities and limitations of practicable increase of calcium content in the wheat crop as a whole.

A more certain and immediately available means of increasing the calcium content of bread is to add calcium salts or milk, or both, in breadmaking. The increasingly common use of salt mixtures as yeast "foods" or "conditioners" by bakers has been mentioned in a previous chapter. Such salt mixtures regularly contain calcium, and the

amount thus introduced, while not very large compared with our nutritional needs, is sufficient to increase measurably the calcium content of the resulting bread.

In Great Britain, an Act of Parliament has authorized the enrichment of white flour with calcium salt, and the United States Food Administration has made such calcium addition optional; but neither of these projects for calcium addition has yet become effective at the time of writing (Aug., 1941).

On the other hand, the addition of milk (chiefly as skim-milk solids) in breadmaking, which significantly enriches the bread in calcium as well as in protein, riboflavin, and some other nutritional factors, has increased markedly in the United States during the past ten or twelve years. It is now reported that most of the baker's bread made in this country, other than that of the so-called French and Italian types, contains skim-milk powder to the extent of about six pounds for each one hundred pounds of flour used. Such an addition of milk solids would rather more than double the calcium content which ordinary white bread would otherwise have.

Thus, to illustrate with simple round figures, bread made from white flour and the other usual ingredients with added salts, such as are com-

monly used as yeast food or conditioner, but with little if any milk, may be expected to average about 0.03 per cent of calcium. On the other hand, if with the other ingredients essentially the same, the above-mentioned "6 per cent" of skim-milk powder be added, the calcium content of the bread becomes about 0.08 per cent. Bread with this calcium content may be considered as very nearly "carrying its share" of the calcium requirement in the normal maintenance nutrition of the adult. If bread be made with skim-milk powder in the proportion of 10 per cent of the weight of the flour, a calcium content of about 0.13 per cent would usually be obtained. Such a bread could be considered as carrying, in proportion to its energy value, its full share of the calcium needed in the nourishment of any normal human adult. According to most statements, the use of such a high proportion of milk powder must be expected to have some slight influence upon the texture of the bread; but undue conservatism on this account should not be allowed to retard the growth of a practice which has so much to commend it from the viewpoint of nutrition.

The calcium requirements of growing children are, of course, relatively higher than the maintenance requirements of adults. It should also be noted that the trend of recent research upon cal-

cium requirements in human nutrition is to reveal these requirements as being somewhat higher than hitherto supposed. Thus, as our knowledge of calcium requirements in human nutrition becomes more exact, we find it becoming an increasingly strong reason for the encouragement of liberal use of milk powder in breadmaking.

IRON, COPPER, AND MANGANESE

In making white flour from wheat, about four-fifths of the iron of the grain is lost to human consumption. The standards tentatively accepted by the United States Food Administration for Enriched bread include an iron content between that of white bread and whole wheat without discrimination as to whether this shall be reached by the addition of iron salt to ordinary white flour or by such modification of the milling process as to retain in the flour more of the iron which the wheat naturally contains. There seems little reason to doubt the nutritional availability either of iron thus artificially added or of the natural iron compounds of wheat. The independent evidence of several investigators shows that, notwithstanding the presence in bran of a considerable amount of indigestible fiber, its iron is well absorbed from the intestinal tract and efficiently utilized in the

body. The approximate average amounts of iron, copper, and manganese in wheat and its chief mill products are shown in Table 1 (page 32).

The iron, copper, and manganese contents of wheat, while making only small figures as stated in percentage, are all high as compared with most other foods. Of copper and of manganese, the losses involved in making white flour are at least as large, relative to the amount present, as in the case of iron. For all three of these elements, the importance of bread as a source varies widely, depending upon the proportion of the entire grain which is included in the bread flour. If one habitually uses bread made from a "high extraction" flour (i.e., containing a high percentage of the wheat) or if even a moderate proportion of the breadstuffs and cereals consumed is in whole-grain form, there should be little danger of shortage of iron in the dietary and probably no danger of shortage of copper and manganese.

Greaves (1940) has described a wheat of unusually high iron content due, in his opinion, mainly to the high iron content of the soil in which the wheat was grown and the active microflora of this soil. We see no reason to doubt the nutritional availability of the extra iron of such a wheat or of the flour milled from it; but, as noted above in the description of the high-calcium wheat

described by the same investigator, there is as yet no assurance that it will be economically feasible to increase the iron content of the wheat crop as a whole to a nutritionally significant degree. Very probably it may continue to be more practicable to increase the iron content of bread either by using a flour having a larger proportion of the wheat kernel or by the addition of iron salt as permitted in Enriched flour and bread, the regulations for which are now (1941) in process of being formulated by the United States Food and Drug Administration.

Rose and Vahlteich (1932) found the iron of whole wheat and of bran, as also of oatmeal, to be effective in hemoglobin formation. Patent flour also fostered hemoglobin to some extent; but patent flour with added iron was not so effective as the same total amount of iron in the form of whole wheat. They concluded that either the iron in oatmeal and whole wheat is more effective than that of white flour enriched with iron, or that the whole-grain products contain something else as well as iron which is favorable to the assimilation of iron and the formation of hemoglobin.

Rose and Kung (1932) found that, compared on the basis of their iron contents, whole wheat and bran were similar to liver in nutritive value for the support of growth and hemoglobin formation.

In still further studies, Rose, Vahlteich, and MacLeod (1934) found the iron of whole wheat and bran more effective for hemoglobin formation than that of lean beef, liver, or egg yolk.

Myers, Remp, and Bing (1935) found the iron of wheat and its mill products to be well utilized in nutrition, that of whole wheat showing in their experiments "practically complete utilization" even though only about half of it reacted *in vitro* as if it were present as inorganic iron. In the later experiments of Free and Bing (1940), the iron of whole wheat again showed higher availability in fact than the too-frequent assumption of *in vitro* work would imply. In this series the discrepancy was not so great because the indicated "inorganic" fraction was 73 to 88 per cent of the iron in the wheat. In feeding experiments with determinations both of hemoglobin formation and of iron retention in the body, the wheat iron was again found to be "fully as available to the organism as an equal amount of iron in the form of ferric chloride." In a personal communication, Dr. Bing tells us of still further (as yet unpublished) evidence to the same effect.

Much evidence, therefore, supports the high nutritive value of the iron of wheat and its mill products.

Chapter V

VITAMIN VALUES

Wheat is of practically no vitamin A value; and shows no evidence of containing vitamin C, unless sprouted, or vitamin D, in any case; but it is rich in vitamins of the B group.

Of these, the ones of chief present importance (1941) to the nutritional aspects of the bread problem are thiamin, nicotinic acid, and riboflavin.

Thiamin is vitamin B_1; nicotinic acid and riboflavin are among the substances which have been differentiated from the earlier concept of a vitamin B_2, now known as the vitamin B_2 group or complex.

Each of these three substances is of such significance as to call for individual consideration, and there are also problems in which the three are involved together.

Thiamin (vitamin B_1)

The substance for which Funk coined the word *vitamine* and which came to be called *vitamin B*

and later *vitamin* B_1 is now commonly designated by the name *thiamin.* (The name *aneurin,* used synonymously by some writers, is unacceptable to the medical profession in the United States because it is held to be therapeutically suggestive.)

The name thiamin, coined to conform—as well as one short word can—to the molecular constitution of the substance, was suggested by R. R. Williams, long an outstanding investigator of this substance and the first to obtain it in such purity and quantity as to permit the complete working out of its chemical nature.

Williams and Spies (1938) summarized fully the knowledge of this substance up to that date from the chemical, medical, and nutritional points of view.

THIAMIN AS A POSSIBLE DANGER POINT IN THE DIETARY

We agree with the position taken by Drummond in his several writings with different coworkers: that while those spending relatively large amounts of money for food may get such ample amounts of all nutrients from other sources that the kind of bread consumed becomes a matter of indifference, one cannot seriously entertain "so optimistic an assumption" when thinking of the re-

stricted purchasing power of the poor and the large extent to which they are bound to depend upon bread as the mainstay of their food supply. Drummond and co-workers furthermore feel, as do Wilder, Williams, and others in the United States, that thiamin constitutes (or did prior to the introduction of Enriched bread) a special danger point in present-day dietaries, largely because of the combined effects of the lowered wheat consumption and the milling of the wheat to a flour of greatly reduced thiamin content, as compared with the conditions of a century or so ago.

Stone-ground wheat flour "of our grandparents" is estimated to have contained about 60 per cent of the thiamin in the wheat. In contrast, the white flour produced by the roller process is reported to contain only 6 to 16 per cent. No longer are we justified in ignoring this difference on the assumption that, in the diversified diets of this country, enough thiamin will always be supplied from other sources. Dr. J. S. McLester in Alabama, Drs. R. M. Wilder and R. D. Williams in Minnesota, and Dr. Soma Weiss in Boston, among others, find that a serious proportion of their patients show evidence of having received suboptimal amounts of thiamin from their usual dietaries. Both the nervous system and the heart may be affected by hitherto unrecognized shortages of thiamin.

Recently, Willcox (1941) has recalled the experience of the British army in Mesopotamia during the first World War. Those from the British Isles who used bread and biscuits made from white flour developed thiamin deficiency (beriberi), while those from India who were similarly situated in other respects but who used a whole-meal flour (atta) escaped this disease. According to some but not other reports, a part of the credit for this protection from beriberi may have been due to a lentil (dal or dhall) which some of the Indians ate but which the English usually did not.

AMOUNT OF THIAMIN NEEDED IN NUTRITION

From a very comprehensive study of the medical and other scientific evidence as to the thiamin contents of diets which, on the one hand, have been found adequate to protect from beriberi or, on the other hand, upon which beriberi has occurred (in however small a proportion of the people subsisting on the diet), Williams and Spies concluded that human beings need between 27 and 30 micrograms * per one hundred non-fat Calories of food consumed or of foodstuffs oxidized in the body. Similar findings as to thiamin

* The microgram (millionth of a gram) is often indicated by the Greek letter gamma (γ) or by the symbol μg.

need in relation to non-fat energy metabolism were obtained in animal experimentation by Elvehjem and co-workers at the University of Wisconsin and by Cowgill and co-workers at Yale. In many other writings, however, Cowgill has discussed thiamin requirement on the basis of total energy metabolism, and apparently the difference between the two bases for the computation of thiamin need has not always been kept in mind. In the Oriental dietaries to which the literature of beriberi has most often referred, the fat content is low and the difference between total calories and non-fat calories is small. In American dietaries, fat usually furnishes about one-third of the calories so that, when the amount of thiamin needed per one hundred non-fat Calories is allowed for every one hundred food Calories, this amounts to increasing the thiamin allowance by about 50 per cent.

Recently, Wilder and R. D. Williams have reported that, by means of very special diagnostic observations, neurasthenic symptoms may be observed at levels of thiamin intake higher than those at which beriberi appears and that more thiamin is therefore needed than was previously supposed. At the same time, so many favorable results from thiamin therapy have been reported that there tends to be an impression that, within

reason, the higher one's thiamin intake, the better.

This combination of circumstances has resulted in a rapid raising of recommended allowances (often called standards) of thiamin. For example, the Committee on Food and Nutrition of the National Research Council now (June, 1941) recommends 1.5 mg. of thiamin per day for an average sedentary man or moderately active woman, that is, about three times as much as the requirement deduced from the very careful and extended studies of Williams and Spies (1938).

This rapid trend to high "standards" makes thiamin one of the substances in which ordinary dietaries most often appear deficient. And as the ordinary milling process of recent decades has excluded about four-fifths to nine-tenths of the thiamin of wheat from the bread flour, thiamin has been the nutrient first and most prominently considered in recent movements to enrich white flour and bread.

Copping (1939) concludes, from a compilation of data from various sources, that whole wheat contains an average of 1.86 International units, that is,* 5.58 micrograms of thiamin per gram; and correspondingly, flour of 94 per cent extraction, 3.60; of 82 per cent extraction, 3.00; of 75

* When the pure substance had become sufficiently available, the International unit was officially redefined as 3 micrograms of actual vitamin B_1, now commonly called thiamin or thiamin chloride.

per cent extraction, 1.20; of 70 per cent extraction, 1.11; of 60 per cent extraction, 0.72 micrograms per gram.

This would mean only about one-fifth as much thiamin in "straight-run" flour and only about one-eighth as much in patent flour as in whole wheat. On the other hand, when wheat is so milled that 82 to 95 per cent or more (depending upon the process used) of the weight of the grain is recovered as bread flour, such a flour can be free from harsh fiber and can be capable of yielding a strong dough and a bread of light texture, while at the same time it may contain the greater part of the thiamin of the grain and at least four times as much thiamin as is contained in the patent and other "low-extraction" flours chiefly used for bread-making during the past two or three decades.

Hence, Copping, writing in 1938 the previously cited paper, which appeared in January, 1939, considered white bread only one-sixth to one-fourth as good a source of thiamin as whole-wheat bread and only one-fourth to one-half as good a source as commercial breads of intermediate character.

During the past two to three years, there has been a rapidly accentuated growth of opinion that something should be done to ensure the general availability of some form or forms of wheat bread

of sufficiently conventional physical properties to be acceptable to consumers and of significantly higher thiamin content than the ordinary American and European white breads of recent decades.

The proposals aimed toward this objective vary greatly both as to the best means of thiamin enrichment of bread and as to the degree of such enrichment which we may most wisely seek in the present state of scientific knowledge and of popular food habits.

According to a report in the *Lancet* for August 3, 1940, the joint committee of the Lister Institute and the Medical Research Council recommended: (1) that wheat be milled to yield not less than 80 to 85 per cent of its weight as flour, (2) that there be no treatment of flour with oxidizing agents or other foreign substance which may be suspected of injuring its nutritive value, (3) that calcium salts be added, and (4) that the use of baking powders be discouraged because of the danger that they may increase the loss of thiamin in the baking process. Fincke and Little (1941) found that the heating necessary to cook wheat-germ muffins had in itself no measurable effect upon their thiamin content but that this was diminished about 26 per cent when baking powder was used.

The January 4, 1941, issue of the *Lancet* quoted Lord Balfour of Burleigh, Chairman of the Med-

ical Research Council, and Lord Woolton, Minister of Food, as reaffirming the recommendations for flour containing the germ, the aleurone layer, and the finer portions of the bran and for the addition of calcium.

DIFFERENT PLANS PROPOSED FOR THIAMIN ENRICHMENT OF BREAD

Some would seek no change in milling or baking methods but simply add pure thiamin (and such other enrichments which may be decided upon) to the familiar white flour or in the making of the familiar white bread.

Others would retain the wheat germ in milling bread flour or return it in the breadmaking so as to effect the desired thiamin enrichment of the bread without changing its appearance or texture, without resort to artificial additions, and with the certainty of improving some of the other nutritive values at the same time as the thiamin content.

And either alternatively or in addition, one can now use in breadmaking a recently developed thiamin-rich yeast—so rich, in fact, as to add very importantly to the thiamin content of the resulting bread, even raising it to whole-wheat levels.

Others would modify the milling process to "increase the extraction" from the 60 to 70 per cent

of a greatly impoverished flour to perhaps 85 to 98 per cent of a flour capable of being made into bread of only slightly different physical properties, although of much higher thiamin and other nutritive values.

Still others would lay the chief emphasis of the reform upon education to the nutritional superiority of whole-wheat bread, in the belief that, if this superiority were generally understood, it would overcome the prejudices of consumers and that those of producers would be revised to conform to the more enlightened consumer demand.

However, some of the outstanding spokesmen for the medical profession are of the opinion that a campaign of general advocacy of whole-wheat bread as the staple bread supply would inevitably encounter medical opposition on the ground that a steady diet of bread containing the harshly fibrous outer layer of the wheat grain is irritating to some people; and even if this is true of only one person in a hundred, it is to this one that the physician owes his professional duty rather than to the ninety-and-nine who digest the whole-wheat bread perfectly well. Logically, it can be argued that the education of the public should be based on the facts that are true of the many, and should not try to deal with the few who react differently and who should therefore be individually instructed by

their physicians. Yet psychologically it is very desirable that any distinct doctrine or project offered to the public in behalf of its better nutrition shall have the undivided and unqualified support of the medical profession.

Hence, the present strong trend of medical and other scientific opinion toward thiamin enrichment of bread is not concentrating so much upon literal whole wheat as upon the other alternatives above mentioned: (1) addition of synthetic thiamin; (2) retention or addition, or both, of wheat germ; (3) use of thiamin-rich yeast; and (4) such modification of the milling process as to remove the extreme outer layer (the roughage of which may be unduly harsh for some people) while retaining most of the thiamin and of the other nutritive values of the wheat.

There are also alternative modes of approach to the problem of the right degree of thiamin enrichment. Some think in terms of "restoration" and would aim to bring the thiamin content of present-day flour either to that of whole wheat or to that of such a "long extraction" flour as would represent 85 per cent or more of the wheat. Others think rather in terms of making artificially refined foods "carry their share" of the thiamin which the consumer needs. The latter point of view appears to have been the more influential in

the formulation of the proposed standards by the United States Food Administration but not to have involved any serious conflict with the other mode of thought. For in a paper published in March, 1941, Wilder, who as chairman of the Committee on Food and Nutrition of the National Research Council has been working in close coöperation with the United States Food Administration, explains that Enriched flour may be made (1) by the addition to white flour of thiamin, nicotinic acid, and iron * in such amounts as to bring the levels of these nutrients approximately to those found in flour milled to include 85 per cent of the wheat or (2) by any suitable process of milling by which the vitamins originally present in the wheat are retained in such proportions as in the "85 per cent extraction" flour.

Schultz, Atkin, and Frey (1941) have reported, as the result of quantitative determinations of thiamin in cereals by their fermentation method, (1) that there are significant differences in the thiamin contents of the cereal grains of different species and (2) that the thiamin content of wheat varies both with varieties and with regional differences.

The thiamin requirement proposed by the

* To these requirements, that of riboflavin is now added and will become effective at a future date not yet fixed at the time of this writing (Aug., 1941).

Food and Drug Administration for flour and bread is low enough to be met by the use of high-thiamin yeast with any ordinary white flour, while —as Frey, Schultz, and Atkin (1940) have pointed out—the use by the baker of both high-thiamin yeast and skim-milk solids provides well for all the known vitamins of the B group without dependence upon artificial preparations.

The level of thiamin required by the official specification for Enriched flour is 1.66 mg. per pound. This corresponds to about 1.0 mg. per pound of bread or about 80 micrograms per one hundred Calories. This is a proportion which would correspond to 2.0 mg. of thiamin in a daily dietary of twenty-five hundred Calories for a relatively sedentary man. For such a man, the "Chart of Recommended Daily Allowances" of the Food and Nutrition Committee of the National Research Council calls for 1.5 mg. of thiamin. Thus it is evident that, from the viewpoint of the relation of thiamin to food calories, Enriched bread fully carries its share of the thiamin which the consumer needs. On the other hand, this bread is not so rich in thiamin as the popular writings about it would lead one to suppose, and the adoption of Enriched bread may not in itself solve the thiamin problem. To get from Enriched bread alone the amount of thiamin suggested by the Na-

tional Research Council Committee's recommendation, it would be necessary for the sedentary man to eat about twenty-four ounces of bread a day, an amount much above the customary level of bread consumption by sedentary people. However, it is both probable and significant that, among dietaries containing about average amounts of other foods, the difference between Enriched and ordinary white bread may often make the difference between a satisfactory and a scanty thiamin intake. The general average of fruits and vegetables in the dietary contains about one part of thiamin in one million parts of their moist weight. This sounds almost negligible, and is too often treated so. As a matter of fact, recent advances of our knowledge of nutrition greatly strengthen the reasons for liberal use of fruits and vegetables in the normal dietary; and, when they are used in as large amounts as we now see to be desirable, they become (collectively) a very important source of thiamin.

The case may therefore be put from this other angle of approach. In dietaries containing such liberal amounts of fruits and vegetables as are desirable, the change from ordinary white bread to bread enriched in *any* of the ways above mentioned may be expected to result in an entirely satisfactory thiamin intake.

NICOTINIC ACID

Recent as is the discovery, it is now well known that nicotinic acid has preventive and curative values against pellagra—much as thiamin has against beriberi, or ascorbic acid against scurvy—though in cases of pellagra other deficiencies are probably more often simultaneously present, as will be explained in connection with riboflavin below.

As an aid in the campaign against the very serious prevalence of pellagra in our Southern States, it was decided to include among the specifications for Enriched flour the requirement that it must contain not less than 6.15 mg. of nicotinic acid or nicotinic acid amide per pound.

As yet, it seems probable that the experimental attempts to measure nicotinic-acid contents of food and nicotinic-acid requirements of nutrition are subject to relatively large errors and that any figures given must therefore be regarded as highly tentative. Thus, as an indication of the tentative nature of the estimates and the lack of knowledge to permit of discrimination as to the relations of age and activity to the needs for these two nutrients, all figures for nicotinic acid in the "Chart of Recommended Daily Allowances for Specific Nu-

trients" (Committee on Food and Nutrition, National Research Council) are put down simply as ten times the corresponding figures for thiamin. The specifications for Enriched flour call for less than four times as much nicotinic acid as thiamin. Hence, if the postulated tenfold relationship of nutritional need is even approximately correct, the consumption of a given amount of Enriched bread would go hardly half as far toward supplying the needed amount of nicotinic acid as of thiamin. It seems clear that the nicotinic-acid standard of Enriched flour should be revised upward at the earliest opportunity. Yet it is meanwhile permissible to hope that, in many borderline cases, pellagra may be prevented by the nicotinic acid of Enriched bread or of bread made from "85 per cent extraction" or any nearer approximation to whole-wheat flour.

RIBOFLAVIN

As we have already intimated, the typical pellagra patient is apt to be the victim of deficiencies of other nutrients as well as nicotinic acid. Among the most frequent of these concurrent shortages are those of thiamin and of riboflavin. Further study has also revealed a serious frequency of ribo-

flavin deficiency even among people whose food supplies are not so poor as to result in pellagra. Hence, as an aid in the prevention of riboflavin deficiency (either as the independent disease *ariboflavinosis* or as a complication of pellagra), it is proposed that Enriched flour and bread shall contain respectively, 1.2 mg. and 0.8 or 0.6 mg. of riboflavin per pound. From the viewpoint of restoration of milling loss, this standard is relatively higher than that for thiamin; but, as a proposal for making the bread carry its share of the body's need for riboflavin as compared with thiamin, it is not quite so high.

The proposed riboflavin standard for Enriched bread is apparently about equal to the riboflavin content of white bread with the "usual 6 per cent" of skim-milk powder, which is unquestionably compatible with a loaf of conventional texture. Milk powder is much preferable to any isolated form of riboflavin in breadmaking because of the value of the protein and mineral nutrients of the milk to the bread.

Much could be said for a bread made with Enriched or whole-wheat flour *and* a liberal proportion of skim-milk powder, for frequently renewed and accentuated emphasis upon the advantages of liberal dietary supplies of riboflavin is one of the

most outstanding features of our newest knowledge of nutrition.

Amounts of riboflavin which have hitherto seemed liberal are now found to be no more than one needs for full protection from the subclinical shortages which we are only just now learning to detect. Thus, Sydenstricker and co-workers (1940) found slight or incipient riboflavin deficiency (manifested by eye or lip symptoms which would usually be regarded as insignificant) not only among the patients but also among the employees of a Georgia hospital. The latter cases they explained as due to "inadequate intake of milk, eggs, and green vegetables." In New York City, not only hospital patients but also school children show a high incidence of such shortage of riboflavin as has previously passed unnoticed; and in Alabama, Spies and co-workers have found this the most frequent of nutritional deficiency conditions among the children of the area which they studied. With borderline cases so frequent, the riboflavin furnished by a proper modern bread might often be the determining factor in the prevention of disease.

And on the other hand, laboratory animal experimentation extending throughout entire life cycles of successive generations is showing that successively more liberal increases of riboflavin in

the food result in successive advances in nutritional well-being and buoyancy or robustness of health, up to dietary levels certainly at least twice that of adequacy and probably considerably higher still.

Chapter VI

THE QUANTITATIVE PLACE OF BREAD IN THE DIET

Early in the development of the newer knowledge of nutrition, McCollum and Davis (1915), in a paper the title of which does not call attention to this part of its contents, reported that wheat fed as sole food reveals dietary deficiencies but that, when supplemented by casein, butterfat, and a suitable salt mixture, wheat might make up very much the largest part of a satisfactory dietary. They emphasized the finding that correction of the mineral content of the wheat was the form of supplementation it most urgently needed.

Steenbock, Kent, and Gross (1918), studying barley, the nutritional characteristics of which are essentially like those of wheat, fully confirmed the importance of supplementation of the mineral content and held that, unless this were done, the addition of even "good" protein may be rather worse than ineffective.

Osborne and Mendel (1919) further showed

that, when suitably supplemented in its mineral content and with butterfat, wheat may constitute a very large part of the diet and supply the entire protein and water-soluble vitamin needs of growth and reproduction in the rat. Parallel diets with white flour in place of whole wheat were unsuccessful; but, as we have previously noted, the proteins of white flour, though they could not support growth by themselves, were yet able to contribute to growth when supplemented by the proteins of milk, eggs, or meat.

Sherman, Rouse, Allen, and Woods (1921) reported results of experiments with simplified dietaries consisting of bread alone or bread with one other food. As these experiments were made with rats, which do not need antiscorbutic food, simplification of the diet could be carried farther, and the proportion of bread in the diet could be carried higher, than would be recommended in human nutrition. This permitted greater comprehensiveness of experimentation and completeness of control, while interpretation of the findings into terms of the human problem can be safeguarded by scientific study in the careful and thorough investigations which have been made upon the differences and the similarities in the chemistry of the nutrition of the two species. Hence, these experiments, like those just above

mentioned, will here be summarized in terms of the direct findings, and the bearings of these and other data upon the problem of the quantitative place of bread in the human dietary will be taken up later in the chapter. The experimental diets were fed to healthy young rats beginning at ages of twenty-four to thirty days or approximately at the end of their infancy. They were kept in clean cages, at comfortable temperature, and with distilled water for drinking available at all times. Those fed white bread only, or bread and apple, or bread and white turnip made little or no growth. With a diet of bread and meat only, there was good growth for a time, then a period of subnormal growth followed by nutritive failure and death. With bread furnishing four-fifths, and milk one-fifth, of the food calories, there was good growth with every outward appearance of good development,* and some young were born but not reared. Thus, the dietary in which white bread furnished four-fifths, and milk one-fifth, of the food calories might be said to suffice for the nourishment of the original animals from the end of their infancy onward but not for the nourishment of successive generations.

This dietary could, however, be made adequate

* Analyses of animals similarly fed have, however, shown a relatively slow calcification of the skeleton when dietary calcium is so low as in this case.

for the nourishment of successive generations of rats, either by increasing the proportion of milk or by replacing the white bread with whole wheat.

Whether the rest of the diet was whole-wheat or white flour or bread, the results were much better when milk furnished 40 per cent, than when it furnished only 20 per cent, of the total food calories.

On the other hand, bread made with milk instead of water and thus containing about 10 per cent of its calories in the form of milk, showed decided superiority over the water bread.

Rose and McCollum (1928), in experiments which covered growth and reproduction in four generations of rats and which used diets containing always 25 per cent of the calories in the form of milk, found results normal and equally good whether white flour furnished 50 per cent of the total food calories or whether one-quarter or one-half of this flour was replaced by other foods, chiefly vegetables. They also stated that, in a long and detailed study of the dietaries of child-caring institutions, children were found to be in good health and making good growth on diets in which breadstuffs and cereals sometimes furnished up to 52 per cent of the total calories; but they did not recommend so high a proportion.

Sherman and Campbell (1924, 1928, 1930)

found that, while a diet of one-sixth whole-milk powder and five-sixths ground whole wheat was adequate for growth, health, reproduction, and lactation generation after generation, yet, when the proportion of milk powder was increased to one-third, still better nutrition resulted.

The following evidences of improved nutrition were found as a result of increasing the proportion of milk in what seemed to be an already adequate diet:

1. More rapid and efficient growth
2. Somewhat larger average size at all ages
3. Earlier maturity, as shown by the age of the female at the birth of her first young
4. Longer duration of reproductive life
5. Greater success in the rearing of the young
6. Better growth of young

Hopkins (1912) had much earlier shown the influence of milk on groups of young rats fed upon a basal diet composed of isolated casein, fat, carbohydrate, and salts.

Roberts (1934) reported on the supplementary values of dry skim milk in institution diets. Dry skim milk was provided for an institution housing 32 children for a period of three months, and the effect on the quality and the quantity of the diets of the individual children was studied in compar-

ison with those of a control institution. Striking improvements were found in the quality of the diets in the experimental group, while that of the control group remained unchanged. The increase in milk amounted to the equivalent of one-third quart or more for 28 of the 32 children with corresponding increases in calcium and phosphorus. This increase was sufficient to bring the total calcium intake of all the 32 children up to the accepted standard of 1.0 gm. of calcium per day. Increases were likewise effective in the other unmeasured constituents, particularly in phosphorus and riboflavin.

An important factor in the problem of improvement of diet is undoubtedly the cost. The above improvements in the quality of the diet cost only fifty to seventy-five cents per day for the 28 to 32 children studied.

The results showed no significant change in the calories ingested by the children in either institution at the end of a three months' period.

This investigation was continued by Roberts and co-workers (1938) and MacNair and Roberts (1938) in their study on the effect of a milk supplement upon the physical status of institutional children. The effects were judged chiefly by: (1) growth in height and weight and (2) ossification of the bones of the wrist.

Three groups of institutional children consisting of 36 children each were followed through a calendar year. Group I remained on the usual institutional diet as the control group. Group II received a supplement of one pint (reconstituted) of evaporated milk. Group III received a supplement of one pint (reconstituted) of irradiated evaporated milk.

The growth of the children given the milk supplement exceeded that of the controls. The roentgenograms of the wrists and hands of 108 children were taken at the beginning and the end of a calendar year. By all methods of comparison, the groups given a supplement showed greater progress than did the control group, the advantage amounting to more than one-third of a year's quota of expected gain and progress in osseous development. There was no significant difference between the two groups receiving milk supplements.

An investigation was carried out in the National Institute for Research, Reading, England, and in the Rowett Institute, Aberdeen, Scotland, to ascertain the effects on growth and health of the amounts of milk usually consumed by children participating in the Milk-in-Schools Scheme, England (viz., one-third pint and, less frequently, two-thirds pint per head daily). This investigation

is of outstanding importance in that it studied systematically a large population with reference to the influence of different amounts of milk on the growth and health of school children. The great value of milk for the growth and health of children was abundantly confirmed by the results of this school feeding test.

Definite improvements in physique, in general appearance, and scholastic ability and, to a somewhat lesser extent, in muscular strength are to be expected from the consumption by school children of one-third pint or, better still, two-thirds pint of pasteurized or raw milk.

Pasteurization was not found to affect the nutritive value of the milk except to reduce its vitamin C content by about 20 per cent and the thiamin content slightly.

The experimental subjects were eight thousand school children, aged five to fourteen years, studied in five areas in England and Scotland. The experiment lasted from February, 1935, to July, 1936.

The diets which the children consumed at home could not be controlled. The supplements were given in school under supervision: Group I, two thousand children, received biscuits as a supplement to enable them to feel that they were also taking part in the experiment. Group II received

a supplement of one-third pint of pasteurized milk. Group III received a supplement of two-thirds pint of pasteurized milk. Group IV received a supplement of two-thirds pint of raw milk.

The children were medically examined by qualified research workers both before and at the completion of the experiment. The results are summarized in Table 2.

TABLE 2

AVERAGE HEIGHTS AND WEIGHTS

All areas. All ages. The average increase in each milk group is expressed as a percentage of the average increase in the biscuit group.

FEEDING GROUP	BOYS		GIRLS	
	Height	Weight	Height	Weight
Biscuits	100.0	100.0	100.0	100.0
⅓ pt. milk, pasteurized	103.3	103.7	101.3	104.1
⅔ pt. milk, pasteurized	106.6	108.9	103.8	109.0
⅔ pt. milk, raw	104.7	109.6	103.4	113.2

Corry Mann (1926), in an investigation undertaken with the object of making an accurate determination of the nutritive value of fresh cow's milk during the school age of life, showed again in a most convincing way that the nutritive value of a dietary considered to be adequate for school children could be strikingly improved by addi-

tions which, in a quantitative sense, were small.

The addition of one pint of milk a day to a diet which previously appeared to satisfy the appetites of growing boys fed upon it, could convert an average annual gain of weight of 3.85 lb. per boy to one of 6.98 lb. and an average annual increase in height from 1.84 in. to 2.63 in.

The foregoing measurable characteristics were accompanied regularly by improved general health and improvement in spirit. The boys who received the extra ration of milk were more alert and showed higher mental and physical fitness than the others.

Those chosen for this experiment were healthy English boys, aged six to eleven years, living in school cottages in the south of England. The minimum observation period was one year; the maximum was three years. Four-year records were made of the diet which was actually consumed at table. This experiment was thus carried on for four years with continuing results essentially as stated above for a typical year. This excellent research has rightly been of very great influence.

Aykroyd and Krishnan (1937) found skim milk to be the cheapest food known in effectively supplementing the diets of certain South Indian institutions. They introduced, with enormous benefit to the children, fairly large quantities of

skim milk reconstituted from New Zealand skim-milk powder.

Fairbanks (1938, 1939) investigated the nutritive values of: (1) water bread, (2) 6 per cent milk-solids bread, and (3) 12 per cent milk solids. These experiments were made with rats. Those rats which received nothing but water bread remained almost stationary in weight and contained, at the end of the experiment, skeletons so poorly calcified as to present great difficulty in mounting. Bread made with 6 per cent milk solids * supported growth at about one-half a normal rate and resulted in much better calcification of the developing skeleton. With twice this proportion of milk solids, the bread supported both better growth and better skeletal development. In his second paper, Fairbanks (1939) further shows that measurements of body length and chemical analyses at the end of the experiment fully confirmed the visual evidence of superior skeletal development with increasing proportion of milk in bread-making.

Fairbanks concludes from the above experiments that the addition of milk solids to a water bread very significantly increases its nutritive value and, further, that a 12 per cent milk-solids

* As previously explained, this expression means 6 parts of skim-milk solids to 100 parts of flour.

bread is of demonstrably higher nutritive value than 6 per cent milk-solids bread.

In 1939, Tobey reported that the most significant change in the formula of modern white bread had been the inclusion of increasing amounts of milk solids. He pointed out that the growth in the use of milk in bread had increased severalfold since 1923, when the American Baking Institute took the initiative in advocating more milk in bread.

EXPLORATORY RESEARCH EXPERIMENTS

In view of the growing use of such amounts of milk solids in baking as might, in the light of the investigations above noted, be expected to influence significantly the nutritive value of the bread, the present writers, during 1939–40, with the aid of a grant to Columbia University from the American Institute of Baking, carried out the exploratory research experiments described in the following pages.

Healthy young rats of the same stock and in the same conditions of housing and general regime as those used in several of the researches mentioned earlier in this chapter, were fed from the end of their infancy upon modern milk bread * alone or

* Made with 6 per cent as much of skim-milk powder as of flour.

upon diets in which this bread constituted the source of 80 per cent of the total food calories.

Dr. Charles N. Frey, Director of Research, Fleischmann Laboratories, New York City, very generously furnished us with the bread used throughout these experiments. This was a white bread of constant formula (No. 20998) made under his direction and containing 6 parts dry skim milk and 1.3 parts of a dough conditioner (consisting of a mixture of salts and flour) to each 100 parts of flour, together with usual amounts of yeast, table salt, malt, sugar, and shortening.

Through the cordial coöperation of Dr. Frey, to whom we wish to express our very great indebtedness, this bread of known composition and constant character was brought directly from his laboratory to ours by messenger every Wednesday morning throughout the experiments here reported.

In certain of the experiments, as will be described, one or more of the following foods were also used: fresh frozen peas, butter freshly purchased in the retail market, sliced dried beef of uniform brand purchased in glass jars, dried whole milk from the barrel lots used in the nutrition research work of our laboratory.

Fresh distilled water was available to all the experimental animals at all times.

In this exploratory research, 18 experimental animals were used. All were healthy young rats of known hereditary background and nutritional history and were taken for experimental feeding when twenty-eight days old, at which initial age they weighed from 41 to 57 gm.

Six of these (3 males and 3 females) were kept individually in round cages of 9 in. diameter. The remaining 12 were divided into four experiment groups ("lots" or "families"), each consisting of 2 females and 1 male, such a group of 3 being housed in a rectangular cage of 12 by 15 in. The room was of comfortable temperature.

Freshly weighed-out portions of the respective foods were fed at a uniform time each day, at which time, if any of the previous day's feeding remained uneaten, it was collected, dried, weighed, recalculated to its original moist weight, and the food-consumption record adjusted. The close daily observation of each experimental animal or family made it possible to adjust the daily allowances of food to the energy needs at all times with very slight correction for unconsumed food. The technique of feeding was such as to ensure that the different articles of food were actually consumed in the relative proportions shown in the summary of the diets in Table 3.

It will be seen that Diet 637 consists of the "6

TABLE 3

KINDS AND PROPORTIONS OF FOODS IN THE EXPERIMENTAL DIETS OF THE PRESENT INVESTIGATION

Diet No.	Constituent Articles of Food	Percentage of Food Calories from Each Constituent
637	Bread (as described)	100
638	Bread (same)	90
	Butter	10
639	Bread (same)	90
	Milk, dried whole	10
635	Bread (same)	80
	Butter	4
	Dried beef	8
	Fresh frozen peas	8
636	Bread (same)	80
	Butter	4
	Dried whole milk	8
	Fresh frozen peas	8

per cent" skim-milk-solids white bread above described, with no other food.

Diets 638 and 639 consist of the same bread with butter only or with milk only, respectively.

Diets 635 and 636 were more diversified, each containing four articles of food, the other three chosen being well suited to supplement the bread. The only difference between these two diets is

that, whereas in Diet 635 dried beef furnishes 8 per cent of the total food calories, in Diet 636 the meat is replaced by enough whole milk to supply the same proportion of the total energy value.

Summary of results.—The male rat (Laboratory No. 84584) which received the milk bread as sole food survived for 108 days, during which time he gained 16 gm. in body weight (a gain of 30 per cent from his initial weight of 54 gm.). The female (No. 84595) which received the same diet of milk bread as sole food survived 94 days with a total gain of 10 gm. In earlier experiments, rats of the same strain and essentially the same age and initial weight, when fed water bread as sole food, lived somewhat less than half as long and gained practically no weight.

The male (No. 84585) receiving the milk bread and the butter gained 86 gm. in 108 days. This indicates that the protein mixture of the milk bread was quite efficient for the support of growth (as, in Chap. IV, we have seen that it is for adult maintenance also). The female (No. 84596) on the same bread-and-butter diet showed in 120 days a gain of 71 gm., thus supporting the indication that this milk bread is at least fairly efficient in meeting the protein requirements of nutrition. The appearance of these animals clearly indicated the benefit they received from the fat-soluble vitamin

content of the butter, without which the ability of the protein of the bread to support good growth could not become manifest. This bread-and-butter diet was, however, too poor in some of the other nutrients (probably one or more each of the water-soluble vitamins and of the mineral elements) to permit fully normal growth. Determination of the body calcium in the male rat at death indicated that his food had been too poor in calcium to permit a normal rate of increase of percentage of body calcium with age.

A higher percentage and much higher amount of calcium were found in the body of the male rat (No. 84586) which was fed nine-tenths of his food calories in the form of the "6 per cent" skim-milk bread and one-tenth in the form of whole milk (Diet 639). In this case there was satisfactory growth and every appearance of good nutritional condition as long as the experiment was continued. The calcium content of this diet, however, seems to have been somewhat too low for the best development of the skeletal system as judged by the quantitative determination of body calcium at the conclusion of the experiment.

Shortage of calcium also seemed the chief limiting factor in Diet 635, which consisted of bread, butter, beef, and peas in the proportions shown in Table 3, the bread furnishing four-fifths of the

total calories. The animals showed fair, but not fully normal, growth, some bowing of the leg bones, and failure to reproduce. With Diet 636, differing only in that milk here replaced the meat of Diet 635, the results were better throughout but not fully up to the normal average. This was due in part to the low calcium content of this diet and probably also to a suboptimal content of one or more of the vitamins of the B group.

This exploratory research, considered in comparison with earlier experiments in this laboratory in which water bread was used, may be taken to indicate an objectively demonstrable nutritional superiority in the bread made with 6 per cent as much skim-milk powder as white flour over the water bread made of similar flour, but may not be taken radically to change the position of bread as a food.

Even when the other foods are most carefully chosen on nutritional grounds and when the bread is made with 6 parts of skim-milk solids to 100 parts of flour, 80 per cent of the food calories in the form of white bread is too high a proportion even for the nutrition of the rat, a species relatively indifferent to the ascorbic- and nicotinic-acid values of the food. For fully satisfactory nutrition of rats, the proportion of bread should be lower than 80 per cent, and of protective foods

higher than 20 per cent, of the total food calories. From many other experiments, it appears that rats can thrive well on diets in which 50 to 60 per cent of the calories are from breadstuffs.

Allowing for more fruits and vegetables in the human food supply, we suggest 40 per cent of the total food calories as an indication of the place of bread in diets satisfactory from both the economic and the nutritional viewpoint.

Both in cities and on farms, families of low income depend largely on bread. This has been true for many generations. Only since the bread has been made of roller-mill flour does this dependence upon it seem to have resulted in serious nutritional deficiencies. Cummings (1940) points out the chronological sequence of the change of milling methods and increasing prevalence of the highly refined nationally distributed mill products over those of local millstones followed by the appearance of pellagra in many parts of the United States. And Drummond has complained that, because of white flour and white sugar, the average Englishman in recent years has received less thiamin (vitamin B_1) than did the half-starved English pauper of a century ago. For, while the latter's food dole was far too scanty, it had the merit of consisting chiefly of whole-wheat bread.

The careful and comprehensive studies of food

consumption by Stiebeling and Phipard (1939) show that, in each of the major regions of the United States, families spending only small amounts of money for food tend to purchase but little milk. It is therefore a matter of very considerable importance to the nutritional adequacy of their dietary supplies of protein, of mineral elements, and of water-soluble vitamins that the bread which they use be made with liberal proportions of dried skim milk. The wholesale cost of skim-milk powder is so low that its use by bakers often necessitates no change in the retail price of bread. If in other cases it does necessitate an increase of a cent a pound in the price of bread, the added cost is more than justified to the consumer by the much greater nutritive value received.

FURTHER CONSIDERATION FROM THE VIEWPOINT OF FOOD HABITS

Hopkins has pointed out that, in the matter of the choice and use of food, *tradition tends to accumulate prejudices as often as truths.*

As our knowledge of digestion and nutrition is developed in comprehensiveness and exactness by scientific research, it should be made the means of re-examination, from time to time, of one or another food habit or tradition as to how far this

rests upon truth and how far upon mere prejudice.

Upon endeavoring to do this with respect to bread, with the knowledge available in the early part of the fifth decade of the twentieth century, we are led to the conclusion that, not only economically but also physiologically, there are good grounds for giving to bread a permanently prominent place in the diet; that, regardless of ability to purchase other foods, a continued liberal consumption of bread is distinctly advantageous to digestion and can be made advantageous to nutrition.

It is for reasons of digestive comfort and nutritional well-being, as well as of pecuniary economy, that we suggest for breadstuffs (including cereal products generally) the relatively prominent place of something like two-fifths of the total calories of the diet.

In discussion of this suggestion, it may be noted that Great Britain and the United States have each habitually taken about one-third of their total food calories in the form of breadstuffs and other cereals; Germany (in peace times), about 40 per cent; Italy, about 41 per cent; France, about 53 per cent. These estimates of Kellogg and Taylor represent the food habits existing before the first World War, probably more nearly normal

than any considerable period since. Can the lower bread consumption in Great Britain and the United States be taken as assurance that dietaries have been better balanced in these countries than in France? Probably not, for in France a maximal proportion of bread is balanced by the prominence of protective foods in the remainder of the diet, while in Great Britain and America a large proportion of the previous bread consumption has been replaced by sugar. This replacement of perhaps a third of the previous bread consumption by sugar has probably not been beneficial. Whether laboratory feeding experiments could readily demonstrate the effect of this change upon nutritional well-being is doubtful; but we believe that the place of bread in the American and British dietary could well be increased to 40 per cent of the total calories if due prominence is given to the protective foods in the balance of the dietary.

By bringing within more reasonable bounds the proportion of our total calories that we take in the form of non-vitamin-bearing foods, we may give the cereals and breadstuffs the suggested position in our dietaries and at the same time give to the protective foods (fruits, vegetables, and milk in its various forms) the increased prominence in the diet which the newer knowledge of nutrition clearly teaches.

It would, of course, require a considerable reform of the conventional American dietary to bring breadstuffs up to 40 per cent, and protective foods up to 50 per cent, of the total calories at the same time; and whether to aim at the realization of both these suggestions or merely to move toward them is an open question for the self-determination of each family. Naturally, too, one will be influenced by the construction placed upon the term "protective foods" in the future and to what extent the present movement may endow bread itself with "protective" properties.

McCollum also has suggested * that wheat may well supply 40 per cent of the energy requirement and added that, if the daily need is twenty-five hundred Calories, a quart of milk will supply about 27 per cent and that the remaining 33 per cent may be chosen largely on the basis of appetite.

The present authors would emphasize the importance of a liberal supply of fruits or vegetables, or both.

McDougall (1939) has studied, under the auspices of the League of Nations, the place of bread in the food supplies of several European countries and the causes of the decrease in per capita con-

* In a brief note in *Food Facts,* recently (1941) confirmed by a personal communication.

sumption of bread during the past few decades. He attributes this to four main causes: (1) General increase in purchasing power has led to a greater consumption of foods which formerly were economically less available; (2) Mechanization of agriculture and industry has diminshed hard manual labor, thus reducing the need for energy (fuel) foods; (3) Sugar has become so cheap as to compete with bread as a fuel food; (4) The newer knowledge of nutrition is leading people to make more use of the protective foods.

It is to be hoped that the growth of appreciation of the protective foods and the saving of human energies by means of machines will continue and that the purchasing power of the people generally will soon begin to increase again.

What here remains a problem for nutrition, then, is the encroachment of sugar upon the dietary place of bread as a fuel food.

McDougall estimated per capita consumption of sugar to have increased fivefold within a century in Great Britain. In the United States, sugar consumption has doubtless increased as much as in these countries of Western Europe, though the available data may not be precisely comparable.

Now that bread is so generally being enriched in its mineral and vitamin values and nutritional knowledge is becoming more widely diffused and

is exerting more influence upon our food habits, it seems logical to expect that bread may recover at least a part of the ground which it has yielded to sugar during the past two generations or so.

Chapter VII

PRESENT TRENDS AND FUTURE PROBLEMS

Probably for some years to come, the bread problem will still present a tentative or transition aspect from more than one point of view.

While some decisions have been reached, others are still to come; and, after officials have taken their stand and promulgated their regulations, consumers will have their decisions to make as to what kinds of bread they shall use and in what proportions to each other and to the dietary as a whole. We believe that our readers will be best served not by any attempt at dogmatic conclusions on such points but rather by the recognition that some problems are still fluid.

The United States Food, Drug, and Cosmetic Act, which for our present purposes may be called the Federal food law, provides that:

"Whenever in the judgment of the Administrator such action will promote honesty and fair dealing in the interest of consumers, he shall promul-

gate regulations fixing and establishing for any food, under its common or usual name so far as practicable, a reasonable definition and standard of identity."

Under this provision of law, the simple words "flour" and "bread" continue to stand for the products for which they have been the common or usual names, that is, for the ordinary white flour and bread of the past few decades. Even though these are now known to be nutritionally impoverished products, the law still gives them a vested interest in the names they have borne.

The proposal to atone, in part at least, for the impoverishment of white flour by the addition to it of vitamins and mineral elements in some form meant a new product needing (for recognition under the Federal food law) a new name.

Enriched flour and *Enriched bread* are the new names decided upon. In each case it is hoped that the definitions and standards now (1941) in course of official formulation may be so worded as to permit the enrichment to be accomplished to the extent that manufacturers find practicable, by the use of milling processes which diminish the impoverishment of the flour, and not of necessity by artificial additions.

Even if full elasticity in this respect is permitted to the term Enriched bread, there will still

be other kinds of bread competing for the consumers' attention. The announcement of hearings on definitions and standards for bread by the Federal Food Administration reads, in part, as follows:

"The Federal Security Agency announced today, June 10, 1941, public hearings under the Federal Food, Drug, and Cosmetic Act on proposed definitions and standards of identity for

(A) Bread, and Rolls or Buns
(B) Enriched Bread, and Enriched Rolls or Buns
(C) Milk Bread, and Milk Rolls or Buns
(D) Cream Bread, and Cream Rolls or Buns
(E) Butter Bread, and Butter Rolls or Buns
(F) Egg Bread, and Egg Rolls or Buns
(G) Honey Bread, and Honey Rolls or Buns
(H) Butter and Egg Bread, and Butter and Egg Rolls or Buns
(I) Milk and Honey Bread, and Milk and Honey Rolls or Buns
(J) Raisin Bread, and Raisin Rolls or Buns
(K) Whole Wheat Bread, and Whole Wheat Rolls or Buns
(L) Breads, and Rolls or Buns, made of Mixtures of Flour, Whole Wheat Flour, Cracked Wheat, Crushed Wheat."

The requirements for Enriched bread will pre-

sumably be designed to be consistent with those for Enriched flour, allowing for such dilution (and in the case of thiamin, such partial destruction) as normally occurs in breadmaking.

The officially proposed standards for Enriched flour * are that each pound shall contain: not less than 1.66 or more than 2.5 mg. of thiamin (vitamin B_1); not less than 1.2 or more than 1.8 mg. of riboflavin; not less than 6 or more than 9 mg. of nicotinic acid; and not less than 6 or more than 24 mg. of iron.

Tobey and Cathcart (June, 1941) consider the term Enriched bread as covering, in the actual practice of bakers, pending official promulgation of Federal regulations: white bread; slightly darker bread made from special process flour; milk bread or raisin bread which contains, in addition to the usual ingredients, proper amounts of thiamin, nicotinic acid, and iron. To these requirements the Food and Drug Administration proposes in due time to add riboflavin.

Tobey and Cathcart (1941) state that the proposed standard for riboflavin usually can be reached by the use of the proper amount of milk solids in white bread. As they point out, methods for the production of Enriched bread include the

* *Federal Register,* April 1, 1941, pp. 1729-37. Already there is a movement for the revision of some of these numerical standards.

use of Enriched flour, the use of vitamin-rich yeast, the use of crystalline vitamins and suitable iron salts for direct addition to the dough, and combinations of these methods with each other (as well as with the use of milk solids as just mentioned).

The best form in which to add iron in the enrichment of flour and bread is still an open question involving both technological and nutritional problems.

"Enriched" (vitamin-rich) yeast has been developed, especially by the researches of Frey and co-workers, to such a degree that, when this new yeast is used in breadmaking (in the same way that ordinary yeast would be), the product has about the same thiamin content as whole-wheat bread.

Free (1940) reports that the use of bread made with such vitamin-rich yeast contributed 34 per cent of the thiamin of the dietary of a group of college women and significantly improved their level of thiamin nutrition.

Williams (1941) outstandingly champions the view that artificial enrichment should be limited to the addition of such kinds and amounts of the nutrients as are indigenous to the food in question. Thus, Enriched bread should, in his view, be bread which, in one or more of its nutrients, is restored as nearly as possible to the level of concen-

tration existing in whole wheat, allowing for the dilution due to the water habitually added in breadmaking.

At the time of the American Chemical Society Symposium, Williams (1941, p. 720) considered it well established that thiamin and nicotinic acid are often deficient in American dietaries and therefore clearly suitable nutrients to be specified in the definition and standard of an "enriched" flour. Riboflavin he regarded as in a somewhat different position because, while there was considerable clinical evidence of widespread deficiency, he thought it "not yet certain" that prevailing American dietaries are lower in riboflavin than a generation or two ago; and he added that systematic quantitative studies of the riboflavin content of modern dietaries are much needed. This need is being met through the investigation of Stiebeling and co-workers of the United States Department of Agriculture. Simultaneously, we are finding in the researches conducted at Columbia University that levels of riboflavin intake more than twice as high as those of minimal adequacy are needed for optimal results. Hence, the general use of bread enriched with respect to riboflavin seems to the present writers to be clearly desirable. But it does not follow that such enrichment should be effected by an artificial addition of riboflavin as such

to flour, for, if it is supplied, instead, by the use of dried milk in breadmaking, the gain in riboflavin will be accompanied by gains in the mineral and protein values as well. In the symposium above mentioned, E. M. Nelson discussed the control problems of food enrichment from the viewpoint of the United States Food and Drug Administration, and H. S. Mitchell spoke upon "what the consumer should know about fortified foods." These aspects, however, are likely to be so much modified by official definitions and standards for bread which are still pending that only this mention of them seems best at the present writing.

Both American and British discussions of the proposed enrichment of flour with thiamin (vitamin B_1) have brought renewed attention to the greater nutritional completeness of flours representing a larger percentage of the grain; and proposals to make more use of such "higher extraction" or "longer extraction" flours in the general bread supply are now receiving more widely favorable consideration than at any time between the middle-eighties and the middle-thirties. *Nutrition Abstracts and Reviews* of January, 1939, devotes its leading article to this subject (Copping, 1939). In this article, Copping points out that one pound of bread, "the amount which may be eaten daily by an adult on an inexpensive

diet," may furnish from less than one-third to more than the whole of the estimated daily requirement of thiamin, according to what kind of flour is used in the breadmaking.

Many discussions of "whole wheat *versus* white" have reference not to a literally entire wheat flour or bread, which may irritate the digestive tracts of a few people, but rather to some product from which the outer and harsher layers of the wheat grain have been excluded. Such an intermediate product is well established as "whole-meal" flour or bread in Great Britain, and it is more largely with this than with literal whole wheat that Copping compares white flour and bread. She gives full recognition to the tasks which would be involved in persuading the millers to change their emphasis from white to "whole-meal" flour, in arranging for such handling and storage as to safeguard against danger of spoilage, and in educating consumers to prefer whole-meal to white bread. But she concludes: "The advantages to be gained in national health would make it well worth while to overcome these difficulties."

Typical of the present trend of British opinion is the report in *Nature* of May 31, 1941, that the Ministry of Food has decided to give its chief emphasis to bread baked from flour of 85 per cent extraction in order that it shall contain:

1. As much as is practicable of thiamin, along with its natural concomitants of riboflavin, nicotinic acid, and other vitamins of the B group
2. Protein in larger amount and of higher nutritive value than that contained in white flour
3. As little as possible of bran of such character as might involve risk of loss of a part of the nutrients through the presence of too much roughage, especially as war conditions tend, in any case, to an increased use of fibrous vegetable food.

On technical and on aesthetic grounds, the bread made from the 85 per cent extraction flour, as milled in Great Britain in 1940–41, was considered excellent. It resembled white bread in flavor and texture, while in color it was pale brown and "not unattractive." (Is this a cautious "Scotch verdict" on what some consider a beautiful brownish-golden color?)

Recent developments in American milling remove the harsh outermost layer of the bran and the dirt from the crease of the wheat kernel, with (we are told) only about 2 per cent loss of weight and no measurable loss of any of the nutrient constituents of the wheat. These developments and the reincorporation of wheat germ in breadmak-

ing should be watched with very close interest.

In this connection it should perhaps be said that some of the experts in nutrition, in their discussions of the newly authorized Enriched bread, have criticized this term as seeming to promise the consumer more than the product actually justifies, because it is enriched in only three or four out of a larger number of nutrients in which white flour is impoverished, as compared with the wheat from which it is made. Also, the enrichments which have been provided for in the official definition (proposed or promulgated) do not in all cases ensure the reaching of whole-wheat levels of the nutrient concerned.

Much of the news writing about Enriched flour and bread has been much more misleading in carrying the implication that, if one uses bread enriched to official standards of, for instance, thiamin, one's thiamin requirement is thereby taken care of. In fact, of course, the official standard attempts *only* to ensure that the bread shall take care of *its share* of the thiamin requirement.

In the above-mentioned British report, it is stated as "known" that intake of calcium in the diets of Great Britain, especially among the poorer classes, is frequently too low for satisfactory nutrition and that calcium is therefore to be added to the national flour. Addition of iron is thought by the British experts to involve a risk to the stability

of some of the other nutrients of the flour and is therefore not recommended for the British "national bread."

Meanwhile, in America the addition of iron to white flour is already being practiced to a considerable extent, while the addition of calcium is still only tentatively suggested.

Thus, even among those who have given special study to the subject, there are still differences of opinion as to relative emphasis and a clear disposition to leave a good deal to the preferences, judgment, and nutritional knowledge of the consumer.

The general position of the Council on Foods and Nutrition of the American Medical Association with reference to "restoration", "fortification", or "enrichment" of processed foods is to consider it essential (1) that the materials added be restricted to those for which greater distribution would be in the interest of the public health and (2) that the food which is proposed for enrichment shall be a suitable vehicle for the vitamins and mineral substances to be restored.

The attitude of the Federal Food and Drug Administration appears to be similar. Suggested requirements * for Enriched bread are:

* Figures here given are the minimum (in each case) numerical standards proposed as the basis for hearings which are not yet (July, 1941) completed and must be followed by an interval before official standards are definitely promulgated.

1. Thiamin, 1 (or 1.1) mg. per pound (which is considerably less than is contained in whole-wheat bread)
2. Riboflavin, 0.8 (or 0.6) mg. per pound (which is just about the amount resulting when 6 per cent skim-milk powder is used in bread-making)
3. Nicotinic acid (or its amide), 4.0 (or 10.0) mg. per pound
4. Iron, 4.0 (or 8.0) mg. per pound (which is considerably less than is contained in whole-wheat bread).

The Nutrition Division of the Office of the Federal Coördinator of Health, Welfare, and Related Defence Activities distributes (1941) a leaflet approved by eight bureaus or services of the Federal government (Bureau of Home Economics, Extension Service, and Consumers' Counsel, United States Department of Agriculture; Children's Bureau; Office of Education; Public Health Service; Federal Security Agency; Consumer Commissioner, National Defence Advisory Commission) and which is entitled "20 Questions on Enriched Flour and Bread." Question 10 and its answer are as follows: *"Should 'enriched' bread be used in place of whole wheat?* No. If you prefer white bread be sure it is enriched."

Thus, the nutrition experts in the various branches of the government service agree that the new Enriched bread is *intermediate* in nutritional desirability between ordinary white bread and bread in which the natural nutrients of the wheat grain are retained. This is also the view of those who gave given most careful study to the subject in Great Britain.

SUMMARY

THE past century has seen great developments in wheat production, milling, and baking. In recent years, however, we have come to realize that, while staple white bread had thus been highly developed and standardized technologically, yet nutritionally it was in some very important respects an impoverished product. From the standpoint of nutritive values, this familiar food was in need of reappraisal and reform.

As a fuel-food—a source of "calories" or of energy in the mechanical sense that a fuel is—the staple forms of bread were and are all substantially alike. The breads of a century ago, those of a decade ago, and those now being introduced, all have energy values of about twelve hundred Calories a pound.

Wheats—and the flours made from them—differ more in their protein contents than in their energy values. Moreover, flours and breads differ more in their *protein values* than in their *protein contents* because the protein mixture of a whole-wheat bread or a bread made with skim-milk pow-

der or one which includes a significant proportion of wheat germ, has a more favorable amino-acid constitution, and therefore a higher efficiency in nutrition, than that of bread made from white flour and water (breads of the so-called French and Italian types).

Hitherto, the commerical grading of flour has run inversely as its mineral content (ash), whereas the newer knowledge of nutrition recognizes some of the mineral elements or ash constituents as of great importance to food values. Following the example of the Committee on Food and Nutrition of the National Research Council, we may here, for the sake of simplicity and conciseness, give specific attention only to calcium and iron, among the mineral elements.

Of calcium, even whole wheat is not a rich source, and the selection of the flour has very much less influence upon the calcium content of bread than has the milk now commonly used in breadmaking. This, however, might be changed if flours with and without calcium enrichment should be made simultaneously available to consumers.

Whole wheat is an excellent source of nutritionally efficient iron; but about four-fifths of it has been and is rejected in the milling of ordinary white flour. Enriched white flour is, in the

United States, to have at least a significant share of the original iron content restored. Also, a somewhat belated attention is now being given to the milling of flours which are sufficiently freed from any such roughage as might be irritating to some people and yet which retain nearly all of the natural iron content.

Whole wheat is a good source of the vitamins of the B group, which have, however, like the iron, been very largely lost in the milling of white flour. In Great Britain, thiamin is to be restored to white flour, or, alternatively, wheat may be so milled that at least 85 per cent of its weight with most of its thiamin content goes into a "long-extraction", darker flour for the making of a more natural modern bread.

Or wheat germ may be incorporated in white bread in sufficient proportion to raise its content of thiamin (and presumably also of riboflavin and nicotinic acid) to the level of a whole-wheat or "enriched" white product.

Other effective methods for the vitamin-enrichment of bread are the use of milk solids and of vitamin-rich yeast in breadmaking. As the yeast is relatively richer in thiamin and the milk relatively richer in riboflavin, the bread will clearly be of greater nutritive value when both these are

used or when both wheat germ and milk are incorporated in the breadmaking.

Thus, there are now being offered, to American consumers at least, white breads the nutritive values of which have been improved in several different ways and breads of "cream" to "golden-brown" color which retain most, or in some cases practically all, of the nutrients rejected in the making of white flour.

Breads nutritionally modernized in any of these ways can logically be given a larger place in the dietary than we should be justified in giving to the nutritionally impoverished bread which has prevailed in our markets during the past three or four decades. Illustrations of experimental evidence of this are cited in Chapter VI.

While the nutritionally improved breads are still bread, that is, are not to be thought of as belonging to any radically new category of food, yet, assuming that increased consumption of bread displaces foods of lower and not those of higher mineral and vitamin values, we believe that bread may now safely be utilized to supply as much as 40 per cent of the calories of the normal diet. We also believe that to give bread this somewhat more prominent place in the diet will frequently be physiologically, as well as economically, advan-

tageous—partly because we now have a varied offering of breads the substitution of which for non-vitamin-bearing foods will nutritionally improve the diet and partly because a liberal proportion of bread in the dietary tends to give to the food-mass as a whole a texture favorable to the comfort and hygiene of the digestive process.

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